Earthwork Design Guide

TDOT Department of Transportation **Roadway Design Division**

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Introduction

An accurate and easily interpreted earthwork report is helpful to correctly estimate the cost of a project, both in terms of money and in terms of time and work. To accurately assess the earthwork for a project, a designer needs to have cut cross-sections, calculated topsoil needs and determined the rock content of the soil, if possible.

Part 1 of this document pulls together information from many sources and provides links for reference. The Designer should be able to find answers to most questions here. Part 2 provides a step-by step guide for calculating topsoil quantities.

Part 1 - Earthwork Quick Guide

Design Guidelines

Details on Earthwork design can be found in the Roadway Design Guidelines, Chapter 2-700.

Specifications Manual

Earthwork is discussed in Part 2 of the TDOT Specifications Manual

Standard Drawings

Not applicable.

TDOT CADD Programs

Details of how to use MicroStation to calculate and record earthwork values can be found in Chapter 15 of the GEOPAK Road Design class manual. Chapter 16 describes cross-sections, including how to incorporate the earthwork data.

Roadway Design Plans

This list below describes where earthwork values can be found in a standard roadway plan set.

- Estimated Roadway Quantities Sheet: The totals of each earthwork type that was calculated will be shown here in cubic yards.
- Tabulated Quantities Sheet: On this sheet, an estimated grading quantities table, such as the one in Figure 1, will be shown. This table can be found in the Estimated Roadway Quantities excel file that will be used for your project. The example below is a balanced example, this one and an unbalanced example is shown in more details in Roadway Design Guidelines, Chapter 2-707.00.
- Cross Section Sheets: For every cross section, a cut, fill, and rock area value will be listed in square feet.

ESTIMATED GRADING QUANTITIES

DESCRIPTION	UNADJUSTED VOLUMES (CY)		ADJUSTED VOLUMES (CY)	BALANCE SUMMARY
	EXC.	EMB.	EXC.	SHRINK = 15 % SWELL = 15 %
MAINLINE	219500	243000	190870	
SIDE ROADS	12500	5490	10870	
PVT. DRIVES, BUSINESS AND FIELD ENTRANCES				
INDEPENDENT DITCHES				EXC. EMB.
TEMPORARY CONSTRUCTION EXITS				253490 VS. -253490
OTHER				
PAVEMENT				
TOPSOIL (EMB.)	5000		4348	AVAILABLE = 0
TOPSOIL (EXC.)	13000		11305	
TOPSOIL (TO REPLACE STRIPPED TOPSOIL)		5000		

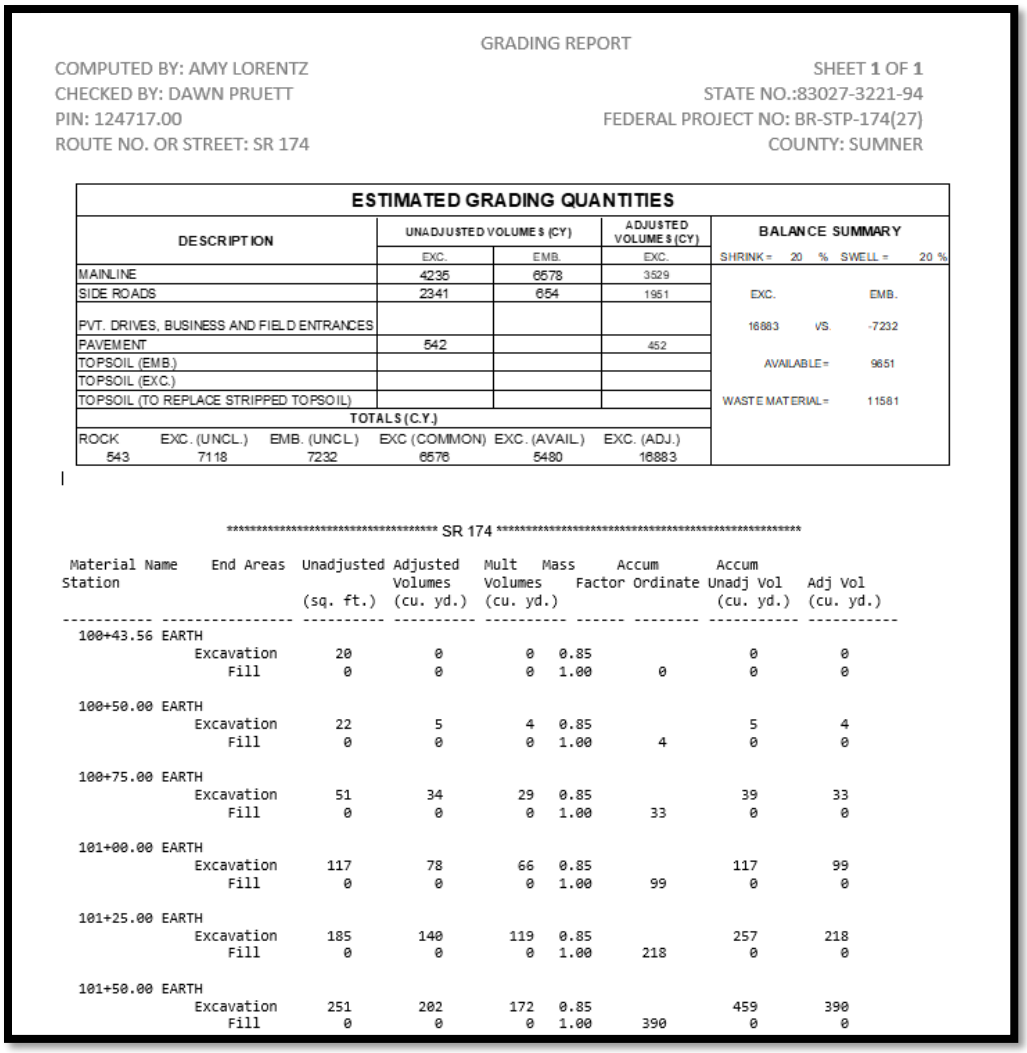
ROCK (C.Y.)		TOTALS (C.Y.)					WASTE MATERIAL = 0
EXC.	EMB.	EXC. (UNCL.)	EMB. (UNCL.)	EXC (COMMON)	EXC. (AVAIL.)	EXC. (ADJ.)	
45000		250000	253490	232000	201740	253490	

Figure 1. Estimated Grading Quantities table, balanced example.

Grading Reports

Grading reports are included in Construction Plan sets. These reports are used by construction contractors to estimate the amount of time, labor and equipment that will be needed. It is useful to separate the mainline estimates from those of side roads, driveways, ditches and culverts. An example of a grading report can be seen in Figure 2 below.

To create a grading report, start with the Grading Report Template file. Edit the header to include the correct information for your project, then paste the Estimated Grading Quantities table in the place the template indicates (removing the instructions). For each major feature of your project (mainline, sideroad, etc), paste the results of the earthwork log file generated by GEOPAK, or any calculations done manually. For readability, separate each log file with a copy of the text box provided in the template, and edit the description.



GRADING REPORT

COMPUTED BY: AMY LORENTZ
CHECKED BY: DAWN PRUETT
PIN: 124717.00
ROUTE NO. OR STREET: SR 174

SHEET 1 OF 1
STATE NO.:83027-3221-94
FEDERAL PROJECT NO: BR-STP-174(27)
COUNTY: SUMNER

ESTIMATED GRADING QUANTITIES

DESCRIPTION	UNADJUSTED VOLUMES (CY)		ADJUSTED VOLUMES (CY)
	EXC.	EMB.	EXC.
MAINLINE	4235	6578	3529
SIDE ROADS	2341	654	1951
PVT. DRIVES, BUSINESS AND FIELD ENTRANCES			
PAVEMENT	542		452
TOPSOIL (EMB.)			
TOPSOIL (EXC.)			
TOPSOIL (TO REPLACE STRIPPED TOPSOIL)			

BALANCE SUMMARY

SHRINK = 20 % SWELL = 20 %

EXC.		EMB.
16883	VS.	-7232

AVAILABLE = 9651

WASTE MATERIAL = 11581

TOTALS (C.Y.)

ROCK	EXC. (UNCL.)	EMB. (UNCL.)	EXC (COMMON)	EXC. (AVAIL.)	EXC. (ADJ.)
543	7118	7232	6576	5480	16883

********** SR 174 **********

Station	Material Name	End Areas	Unadjusted Volumes (sq. ft.)	Adjusted Volumes (cu. yd.)	Mult Volumes (cu. yd.)	Mass Factor	Accum Ordinate	Accum Unadj Vol (cu. yd.)	Accum Adj Vol (cu. yd.)
100+43.56	EARTH								
		Excavation	20	0	0	0.85		0	0
		Fill	0	0	0	1.00	0	0	0
100+50.00	EARTH								
		Excavation	22	5	4	0.85		5	4
		Fill	0	0	0	1.00	4	0	0
100+75.00	EARTH								
		Excavation	51	34	29	0.85		39	33
		Fill	0	0	0	1.00	33	0	0
101+00.00	EARTH								
		Excavation	117	78	66	0.85		117	99
		Fill	0	0	0	1.00	99	0	0
101+25.00	EARTH								
		Excavation	185	140	119	0.85		257	218
		Fill	0	0	0	1.00	218	0	0
101+50.00	EARTH								
		Excavation	251	202	172	0.85		459	390
		Fill	0	0	0	1.00	390	0	0

Figure 2 Example of Grading Report.

Other Helpful Material

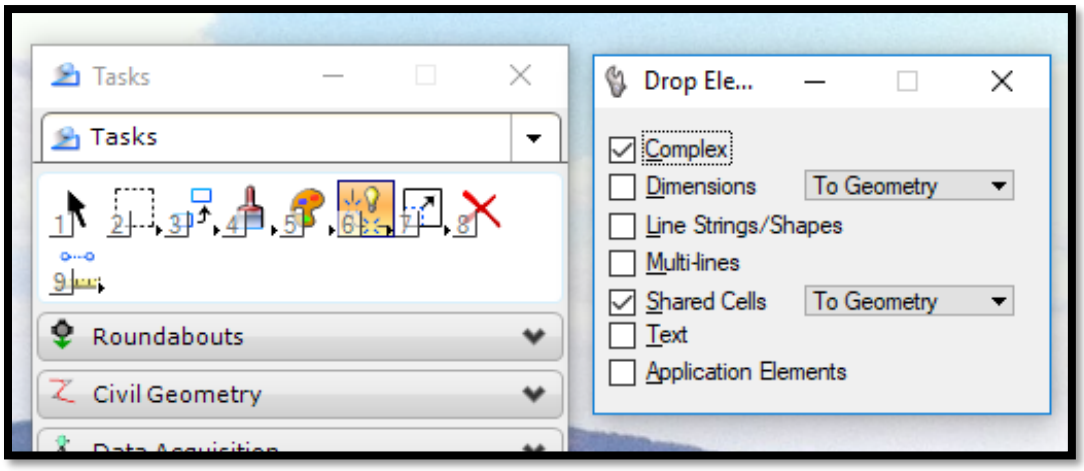
FHWA Earthwork Design

Part 2 – Computing Topsoil Quantities

The following is a step-by-step tutorial on using MicroStation to calculate topsoil quantities

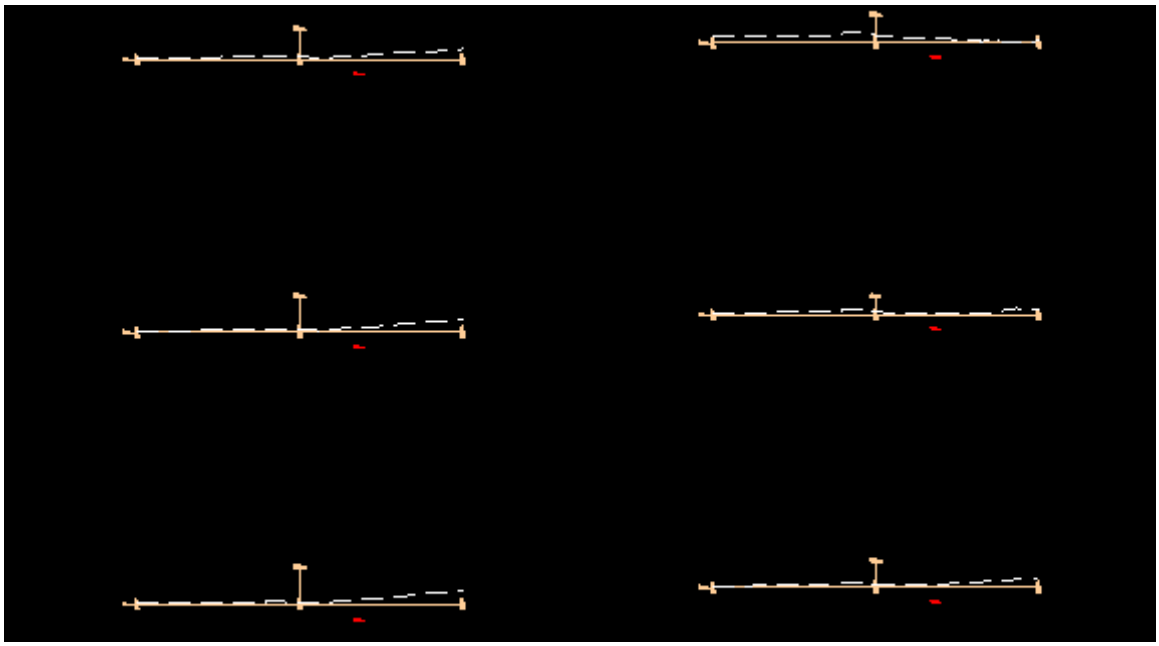
1. Drop Complex Elements

Before running the cross sections, the first step is to go into your Survey DGN file and drop the status on the edge of pavement lines. The program will not run for complex elements.



2. Run Existing Ground Cross Sections on Project

This example is SR 95 from Station 287+00 to Station 289+50 (6 sections):



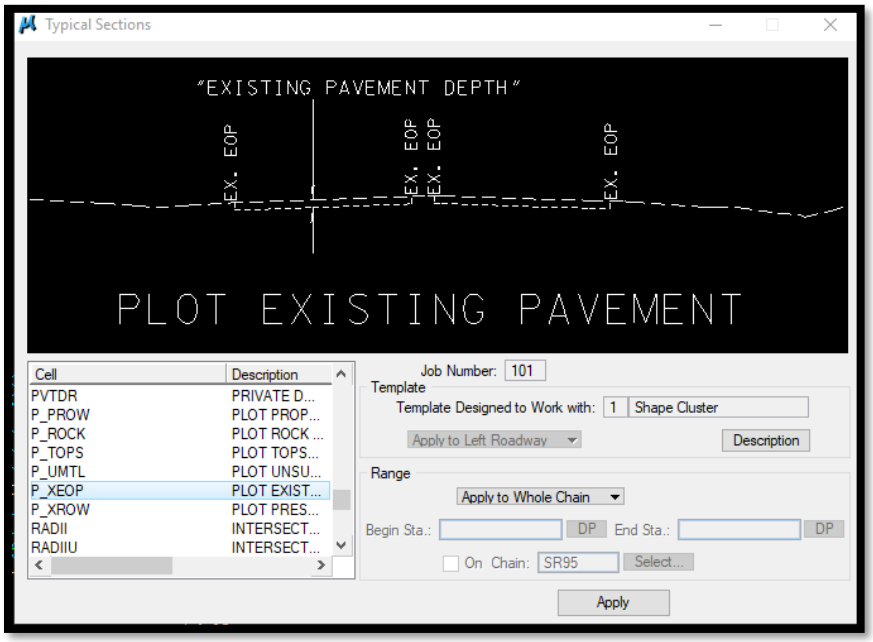
3. Plot existing pavement on cross sections

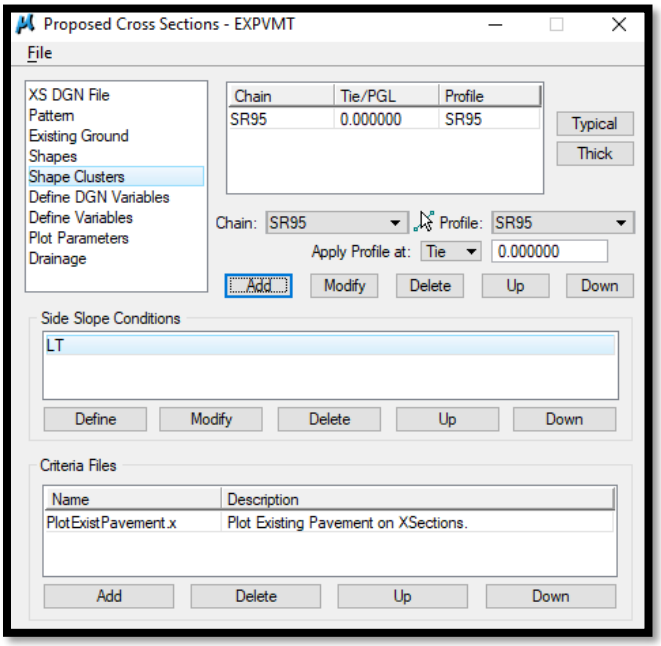
GEOPAK Project Manager>Proposed Cross Sections

Create Run “EXPVMT”

<u>Shape Clusters:</u>

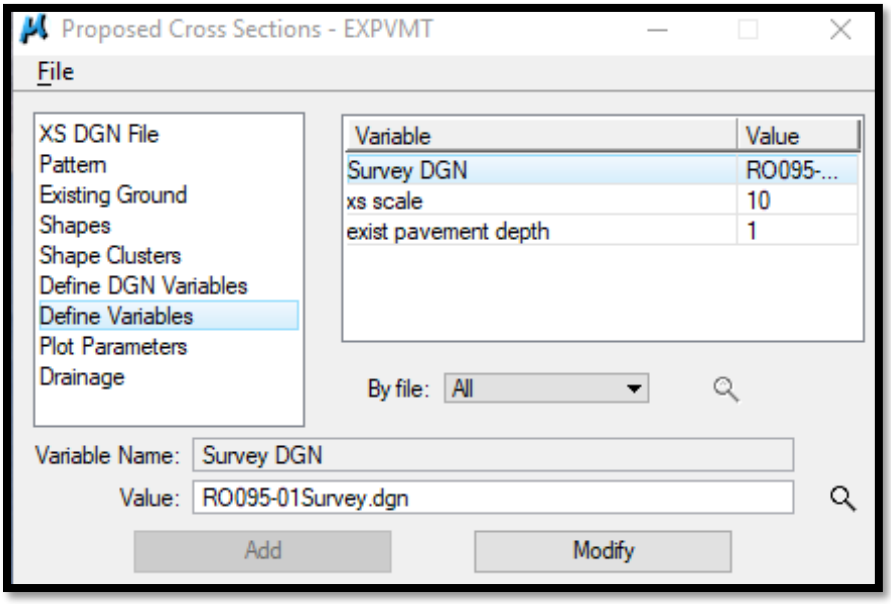
Select template “P_XEOP”





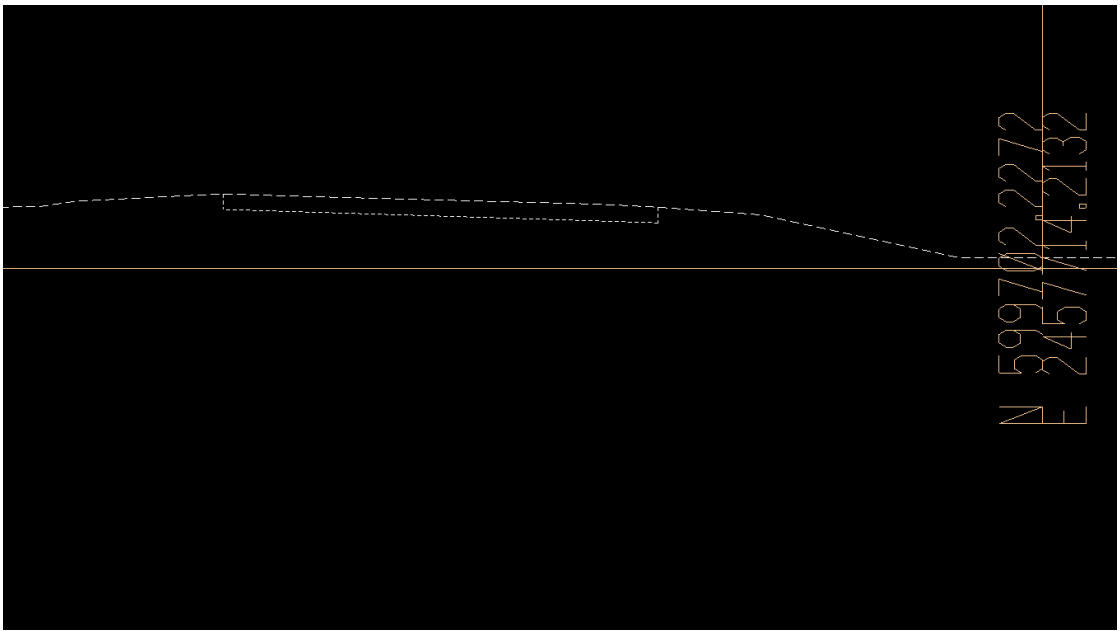
Define Variables:

Change the Survey DGN name to the file for your project



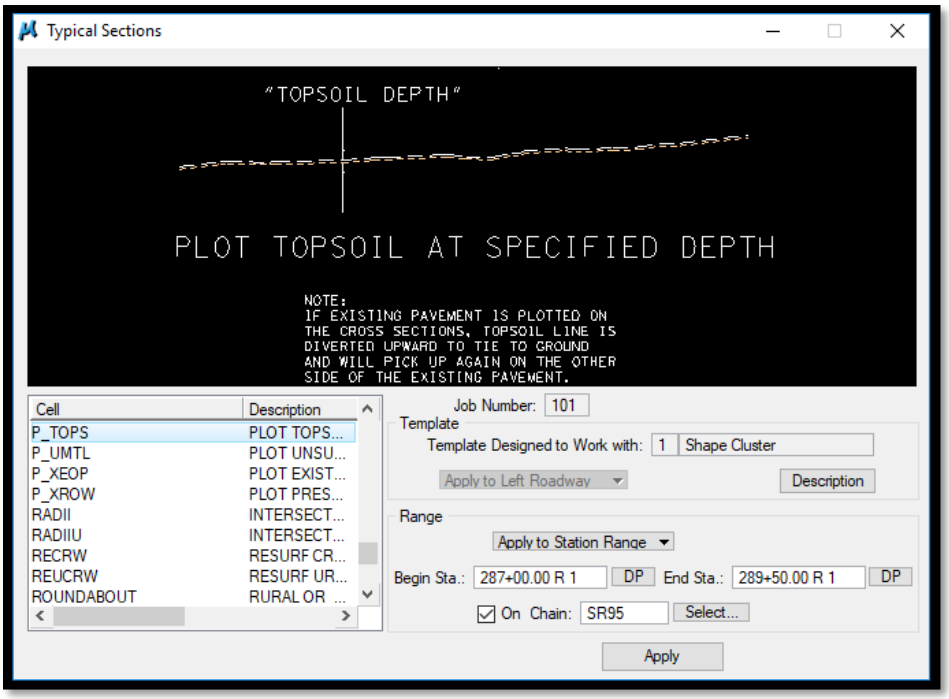
All other settings can stay the same as for other cross section runs

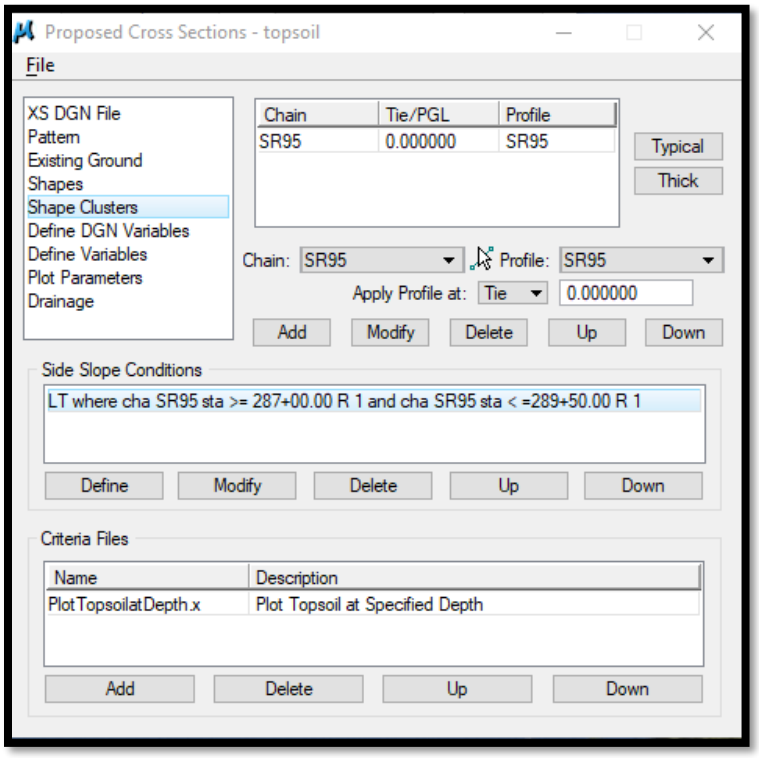
Then run cross sections:



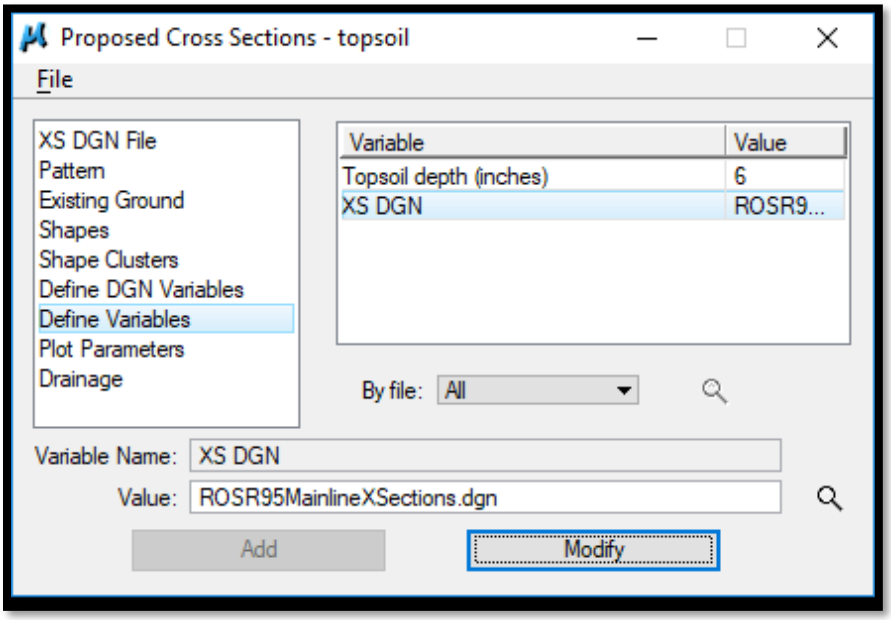
4. Plot Existing Topsoil Layer

Open GEOPAK Project Manager. Go to Proposed Cross Sections. Create a new run “topsoil”, or copy the Proposed cross section run, and use the same settings with the exception of “Shape Clusters”. Delete the previous clusters, add new cluster using the template P_TOPS

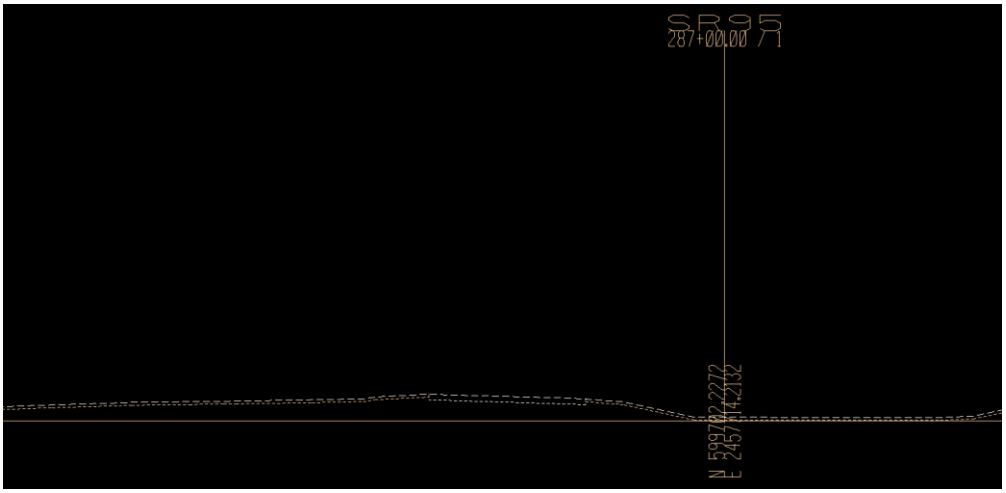




In “Define Variables” edit the “XS DGN” file:



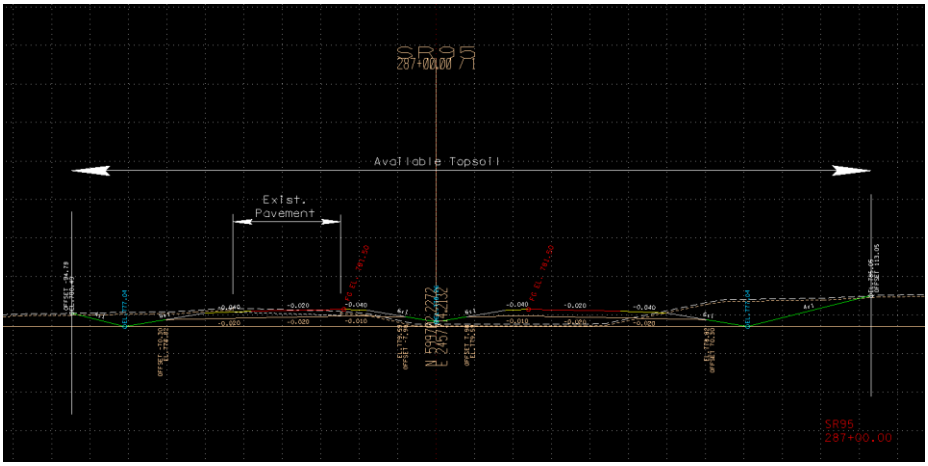
Next - select “Run”



The topsoil layer is plotted on the cross sections at a default depth of 6 inches. This is to allow for 100% Shrinkage. See Roadway Design Guidelines Chapter 2-706.00 Topsoil Requirements for Earthwork Balances for more information regarding the shrinkage guidelines for topsoil. Notice it excludes the existing pavement but plots along the entire ground line of the cross sections.

The available topsoil is the ground line (dashed) between the excavation limit lines, excluding the existing pavement area.

5. Run Proposed Cross Sections

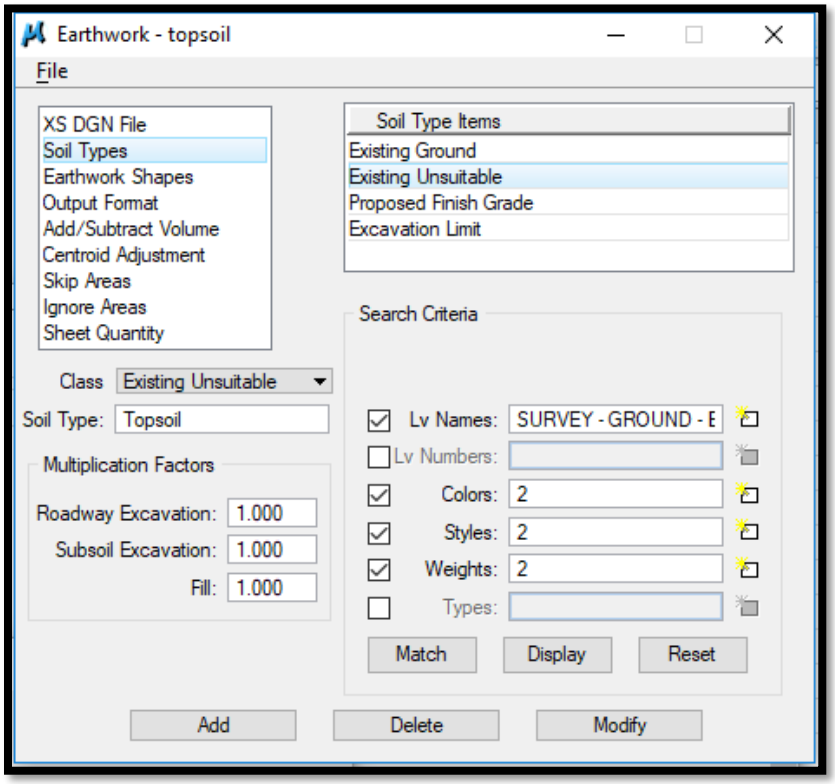


6. Run Earthwork

Create run “Topsoil”

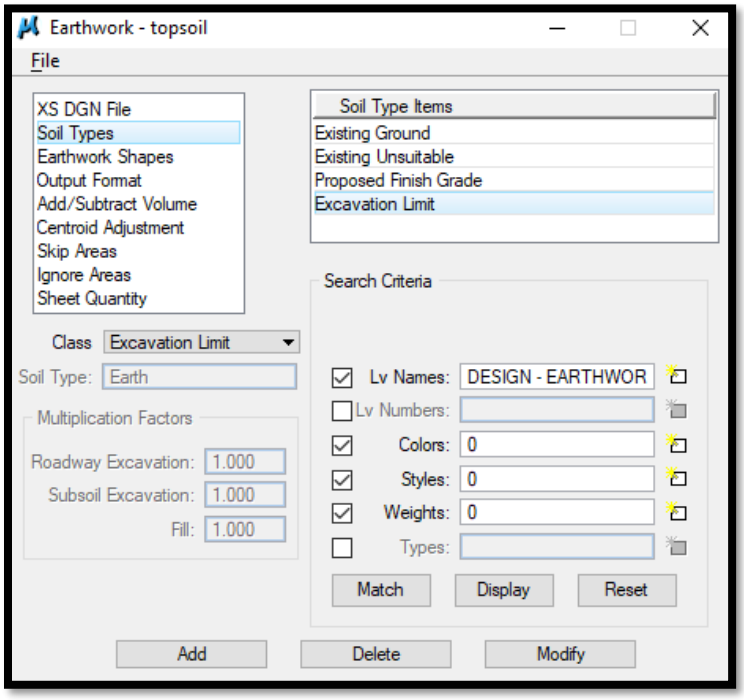
Make settings as shown in GEOPAK Road Manual Exercise 15. In Soil Types, add settings for Topsoil and Excavation Limit as shown-

<u>Topsoil Settings:</u>



Level Name - SURVEY-GROUND- Bottom of Topsoil Layer

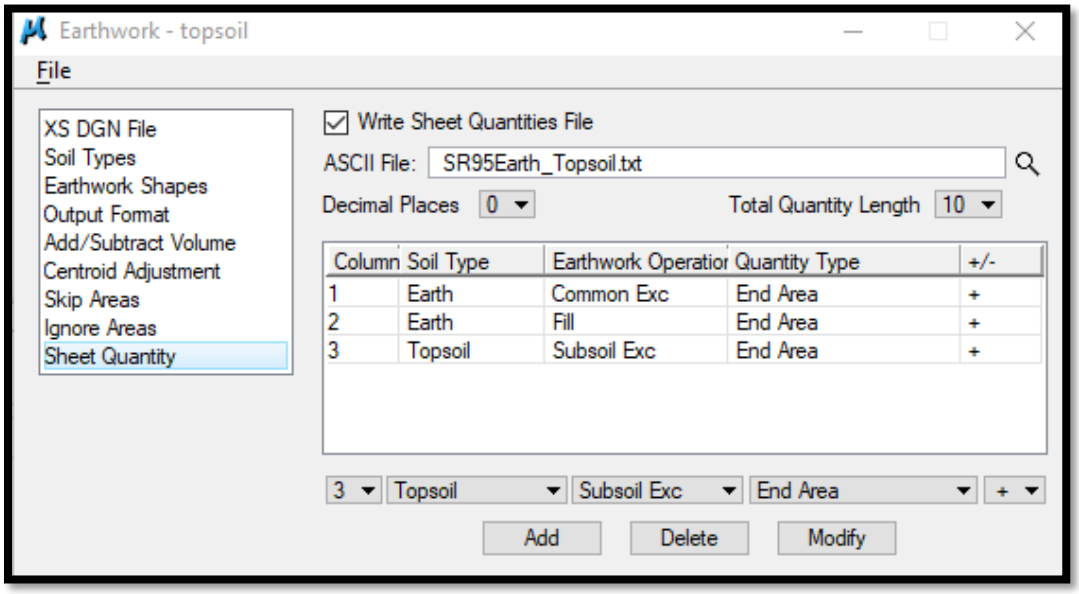
Excavation Limit:



Level Name - DESIGN-EARTHWORK- Excavation Limit Lines

Sheet Quantity

Add column for Topsoil and change the ASCII File Name to *Project_Topsoil.txt*



When all settings are made, then select File>Run

Output file SR95Earth_Topsoil.txt:

SR95Earth_Topsoil - Notepad

File Edit Format View Help

```
Station                                  Volumes    Volumes    Factor Ordinate
                              (sq. ft.)  (cu. yd.)  (cu. yd.)
---------- ---------------- ---------- ---------- ---------- ------ --------
  287+00.00 EARTH
               Common Exc      319.2          0          0   1.00
             Subgrade Exc        0.0          0          0   1.00
              Subsoil Exc        0.0          0          0   1.00
                   Fill        132.6          0          0   1.00        0
            TOPSOIL
               Common Exc       55.0          0          0   1.00
             Subgrade Exc        0.0          0          0   1.00
              Subsoil Exc       34.9          0          0   1.00
                   Fill         0.0          0          0   1.00        0
              Mass ordinate for TOPSOIL = 0

  287+50.00 EARTH
               Common Exc      244.9        522        522   1.00
             Subgrade Exc        0.0          0          0   1.00
              Subsoil Exc        0.0          0          0   1.00
                   Fill         82.8        199        199   1.00      323
            TOPSOIL
               Common Exc       61.4        108        108   1.00
             Subgrade Exc        0.0          0          0   1.00
              Subsoil Exc       26.6         57         57   1.00
                   Fill         0.0          0          0   1.00      323
              Mass ordinate for TOPSOIL = 165

  288+00.00 EARTH
               Common Exc      125.6        343        343   1.00
             Subgrade Exc        0.0          0          0   1.00
              Subsoil Exc        0.0          0          0   1.00
                   Fill        139.4        206        206   1.00      460
            TOPSOIL
               Common Exc       42.2         96         96   1.00
             Subgrade Exc        0.0          0          0   1.00
              Subsoil Exc       39.9         62         62   1.00
                   Fill         0.0          0          0   1.00      460
              Mass ordinate for TOPSOIL = 323
```

Continued:

SR95Earth_Topsoil - Notepad

File Edit Format View Help

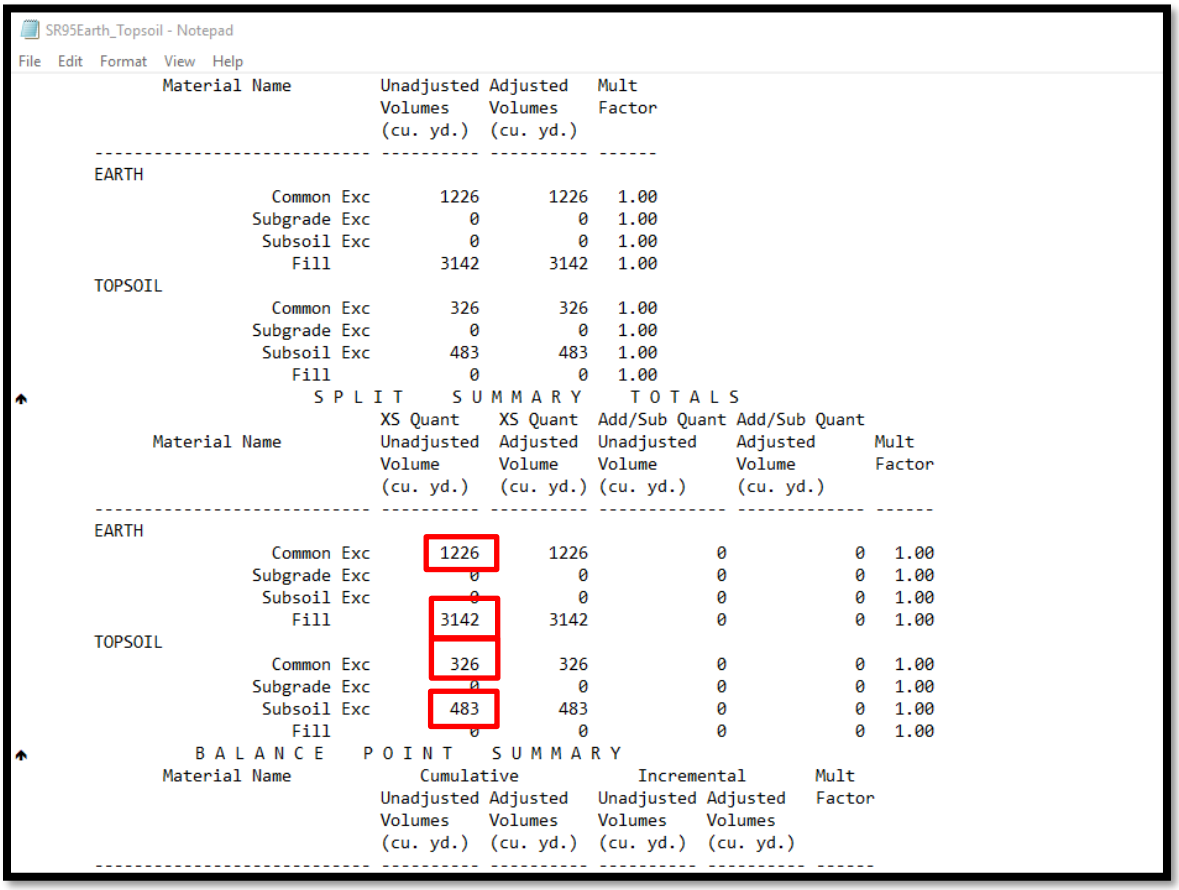
```
 288+50.00 EARTH
               Common Exc      55.7        168        168   1.00
             Subgrade Exc       0.0          0          0   1.00
              Subsoil Exc       0.0          0          0   1.00
                   Fill       309.8        416        416   1.00      212
           TOPSOIL
               Common Exc      22.8         60         60   1.00
             Subgrade Exc       0.0          0          0   1.00
              Subsoil Exc      52.6         86         86   1.00
                   Fill         0.0          0          0   1.00      212
              Mass ordinate for TOPSOIL = 469

 289+00.00 EARTH
               Common Exc      40.6         89         89   1.00
             Subgrade Exc       0.0          0          0   1.00
              Subsoil Exc       0.0          0          0   1.00
                   Fill       429.7        685        685   1.00     -384
           TOPSOIL
               Common Exc      12.4         33         33   1.00
             Subgrade Exc       0.0          0          0   1.00
              Subsoil Exc      57.8        102        102   1.00
                   Fill         0.0          0          0   1.00     -384
              Mass ordinate for TOPSOIL = 604

 289+50.00 EARTH
               Common Exc      35.6         71         71   1.00
             Subgrade Exc       0.0          0          0   1.00
              Subsoil Exc       0.0          0          0   1.00
                   Fill       669.0       1017       1017   1.00    -1330
           TOPSOIL
               Common Exc       9.5         20         20   1.00
             Subgrade Exc       0.0          0          0   1.00
              Subsoil Exc      66.3        115        115   1.00
                   Fill         0.0          0          0   1.00    -1330
              Mass ordinate for TOPSOIL = 739

 290+00.00 EARTH
               Common Exc       0.0         33         33   1.00
             Subgrade Exc       0.0          0          0   1.00
              Subsoil Exc       0.0          0          0   1.00
                   Fill         0.0        619        619   1.00    -1916
           TOPSOIL
               Common Exc       0.0          9          9   1.00
             Subgrade Exc       0.0          0          0   1.00
              Subsoil Exc       0.0         61         61   1.00
                   Fill         0.0          0          0   1.00    -1916
              Mass ordinate for TOPSOIL = 809
XS-NOELEM No cross-section elements found at
```

Continued:



SR95Earth_Topsoil - Notepad

File Edit Format View Help

Material Name	Unadjusted Volumes (cu. yd.)	Adjusted Volumes (cu. yd.)	Mult Factor
EARTH			
Common Exc	1226	1226	1.00
Subgrade Exc	0	0	1.00
Subsoil Exc	0	0	1.00
Fill	3142	3142	1.00
TOPSOIL			
Common Exc	326	326	1.00
Subgrade Exc	0	0	1.00
Subsoil Exc	483	483	1.00
Fill	0	0	1.00

S P L I T S U M M A R Y T O T A L S

Material Name	XS Quant Unadjusted Volume (cu. yd.)	XS Quant Adjusted Volume (cu. yd.)	Add/Sub Quant Unadjusted Volume (cu. yd.)	Add/Sub Quant Adjusted Volume (cu. yd.)	Mult Factor
EARTH					
Common Exc	1226	1226	0	0	1.00
Subgrade Exc	0	0	0	0	1.00
Subsoil Exc	0	0	0	0	1.00
Fill	3142	3142	0	0	1.00
TOPSOIL					
Common Exc	326	326	0	0	1.00
Subgrade Exc	0	0	0	0	1.00
Subsoil Exc	483	483	0	0	1.00
Fill	0	0	0	0	1.00

B A L A N C E P O I N T S U M M A R Y

Material Name	Cumulative Unadjusted Volumes (cu. yd.)	Cumulative Adjusted Volumes (cu. yd.)	Incremental Unadjusted Volumes (cu. yd.)	Incremental Adjusted Volumes (cu. yd.)	Mult Factor

Earth (Common Exc.) = 1226 c.y.

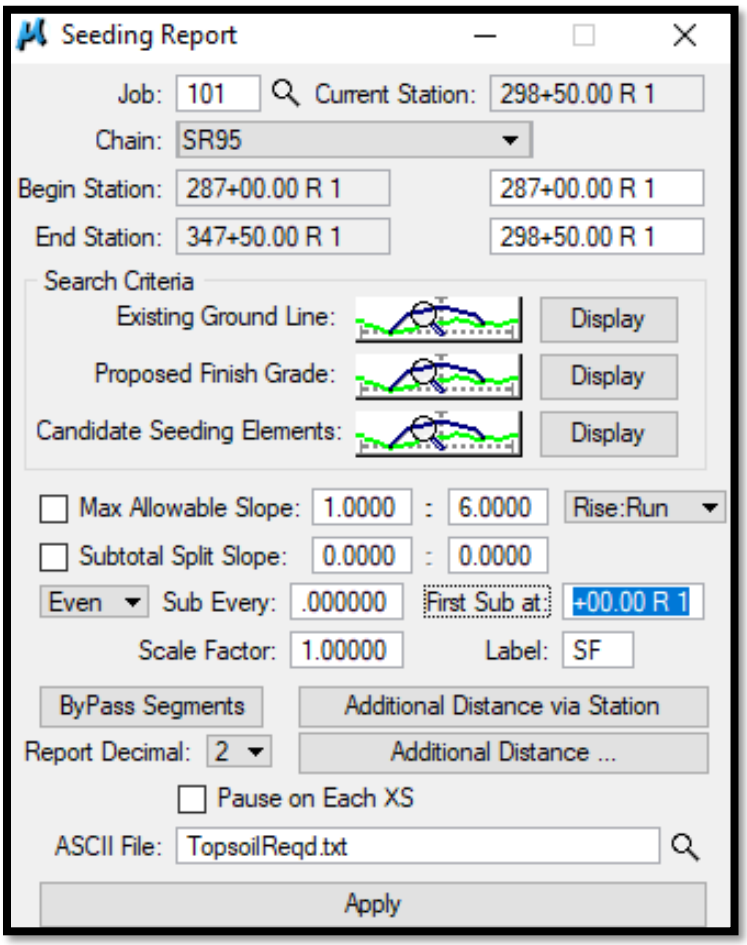
Emb. = 3142 c.y.

Available Topsoil = 326 c.y. + 483 c.y. = 809 c.y.

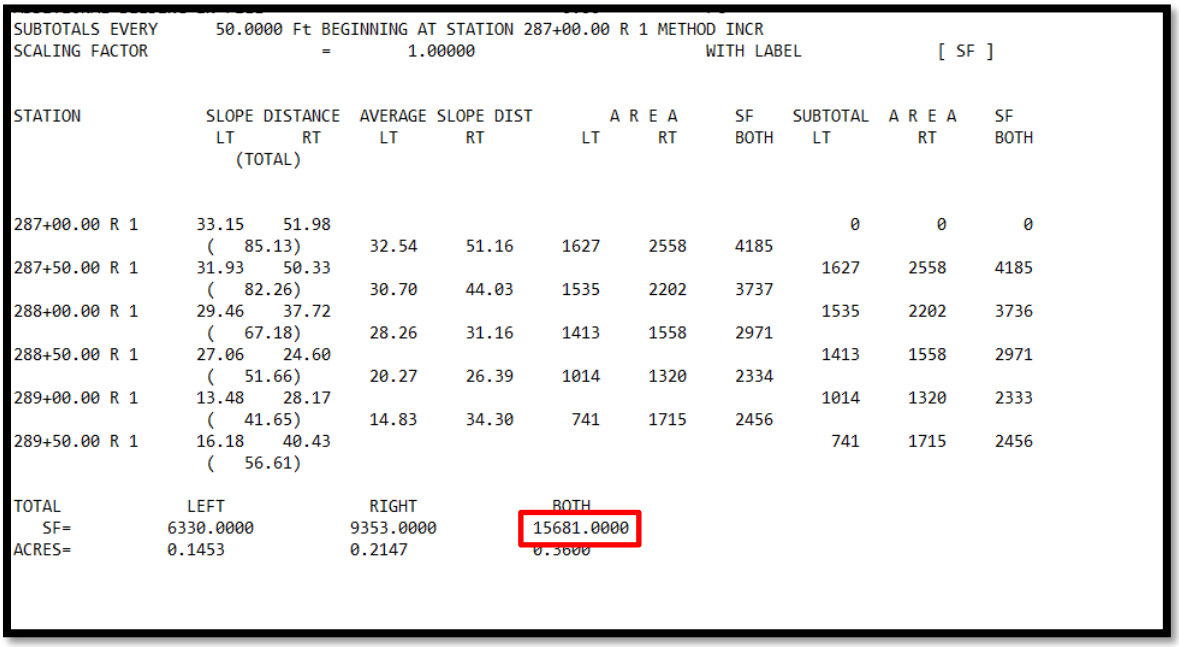
7. Required Topsoil

Since topsoil will be required on all slopes, calculate the surface of the proposed fill and cut slopes and multiply by the thickness of the required topsoil (3”)

In the GEOPAK Road Couse Guide, reference Exercise 17 (Cross Section Reports) to calculate the surface area (seeding and sodding). In step 5 of Exercise 17, use the setting **Even at 50** for the Subtotal option. For the ASCII File name, use TopsoilReqd.txt.



Output file TopsoilReqd.txt:



```
SUBTOTALS EVERY      50.0000 Ft BEGINNING AT STATION 287+00.00 R 1 METHOD INCR
SCALING FACTOR                =        1.00000                      WITH LABEL             [ SF ]


STATION             SLOPE DISTANCE  AVERAGE SLOPE DIST        A R E A      SF    SUBTOTAL  A R E A    SF
                     LT       RT      LT       RT          LT      RT      BOTH    LT         RT      BOTH
                       (TOTAL)


287+00.00 R 1      33.15    51.98                                                    0        0        0
                    (   85.13)       32.54     51.16     1627     2558     4185
287+50.00 R 1      31.93    50.33                                                 1627     2558     4185
                    (   82.26)       30.70     44.03     1535     2202     3737
288+00.00 R 1      29.46    37.72                                                 1535     2202     3736
                    (   67.18)       28.26     31.16     1413     1558     2971
288+50.00 R 1      27.06    24.60                                                 1413     1558     2971
                    (   51.66)       20.27     26.39     1014     1320     2334
289+00.00 R 1      13.48    28.17                                                 1014     1320     2333
                    (   41.65)       14.83     34.30      741     1715     2456
289+50.00 R 1      16.18    40.43                                                  741     1715     2456
                    (   56.61)

TOTAL              LEFT              RIGHT             BOTH
   SF=          6330.0000         9353.0000         15681.0000
ACRES=          0.1453            0.2147            0.3600
```

Multiply the proposed slope area by the required thickness:

15681 s.f. x 3 in x 1ft/12 in = 3920 c.f.

3920 c.f. x 1 c.y./27 c.f. = 145.19 c.y. (This is the required topsoil)

Refer to Chapter 2-706.00 Topsoil Requirements for Earthwork Balances in Roadway Design Guidelines for the relationship of topsoil to total earthwork.

Topsoil = Available (calculated in Step 5) – Required. = 809c.y -146 c.y. = 663 c.y.)

Earthwork Balances:

30% Shrinkage

Road & Drainage Exc (Uncl.) (Item 203-01) = Common Exc (calculated in Step 5) – Topsoil = (1226 c.y. – 663 c.y.)/1.30 = 433 c.y.

Borrow Exc (Uncl.) (Item 203-03) = Fill (calculated in Step 5) – Road & Drainage Exc = (3142* – 433) x 1.30 = 3522 c.y.